EFFECT OF CERTAIN COMPOUNDS OF BARIUM AND STRONTIUM ON THE GROWTH OF PLANTS

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INTRODUCTION

Although it has been known for more than a century that plants are able to extract appreciable amounts of the relatively insoluble compounds of barium contained in soils, very little scientific investigation has been made to determine whether or not the compounds of this element have any specific function in the vegetable economy. Because compounds of barium are poisonous when taken into the animal body, there appears to be a general impression that these compounds would exert a similar influence upon plants.

In a former investigation [1] the writer has shown that small amounts of barium can be readily detected and determined quantitatively in the ash of tobacco, corn, potatoes, and a number of other plants grown under normal conditions in the field. Since soils contain only very small amounts of barium, necessarily in the form of relatively insoluble compounds, it is a question of considerable scientific interest how and why it is that notable amounts of this element are absorbed and apparently assimilated by plants, under normal conditions of growth. The object of the present investigation was to determine the effect of some of the well-known compounds of barium and of the closely related metal, strontium, upon the growth of plants.

EXPERIMENTAL WORK

Preliminary experiments consisted in growing plants in nutrient solutions to which were added certain compounds of barium, soluble as well as insoluble. It soon developed that plants could be grown in a nutrient solution containing moderate amounts of barium nitrate or carbonate, whereas an equal amount of the chlorid or sulphate produced a decided toxic effect. After having determined that the plants selected for the water-culture experiments were tolerant of barium carbonate and nitrate, it was decided that a method more nearly approximating the normal conditions under which plants are grown would be a better procedure. Accordingly the plan was adopted of growing the plants in barium-free sand contained in earthenware pots to which the necessary basal plant-food ration could be added, together with the desired compounds of barium.

[1] McHargue, J. S. THE OCCURRENCE OF BARIUM IN TOBACCO AND OTHER PLANTS. *In* Jour. Amer. Chem. Soc., v, 35, no. 6, p. 826–834. 1913.

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COWPEAS

In the first series of experiments twelve 1-gallon earthenware jars were filled with a clean quartz sand that contained very little plant food. To each of the pots of sand was added the following basal plant-food ration: 10 gm. of calcium carbonate, 10 gm. of tricalcium phosphate, 5 gm. of magnesium carbonate, 4 gm. of potassium nitrate, 2 gm. of potassium chlorid, and 2 gm. of sodium thiosulphate. In addition to this plant food, varying amounts of barium carbonate were added to all the pots except the first, which served as a check against any other one pot in this series of experiments. Cowpeas (*Vigna sinensis*) were planted in the sand in the pots, and during the time the plants were making their growth the sand was kept moist with clear hydrant water. Previous to starting the experiment, 100 liters of hydrant water were evaporated to dryness and the residue thus obtained examined for barium, but none was found. In another experment 25 liters of water flowing from the drain tiles on the Experiment Station farm were collected and evaporated. The residue thus obtained was examined for barium compounds, but none were found.

The cowpea plants were allowed to grow until they were about 10 to 12 inches tall. They were then taken up in such manner as to preserve the roots intact, and the adhering sand was washed off as well as possible. The photograph reproduced in Plate 24, A, was taken two weeks after planting; that shown as figure B, after the plants were removed from the sand in which they grew.

Table I shows the amount of barium carbonate added to each pot and also the weight of the air-dry plants that grew in each of the pots.

TABLE I.—*Effect of barium carbonate upon the growth of cowpeas—First series*

Pot. No.	Quantity of barium carbon-ate added to soil.	Weight of 10 air-dried plants.	Pot No.	Quantity of barium carbon-ate. added to soil.	Weight of 10 air-dried plants.
	Gm.	*Gm.*		*Gm.*	*Gm.*
1 (control)	None.	9.15	7	5	11.40
2	0.5	12.00	8	6	10.90
3	1	11.20	9	8	11.15
4	2	10.15	10	10	10.80
5	3	9.50	11 [a]	5	....
6	4	10.55	12	5	11.65

[a] This pot received no calcium carbonate, and all the plants died.

From the results obtained in this experiment it is to be observed that there were appreciable increases in the yields of all the plants grown in the presence of barium carbonate and calcium carbonate over that of the control pot. In the absence of calcium carbonate, however, the action of the barium carbonate was strongly toxic, as shown by the failure of the plants in pot 11.

The effect of the barium compound upon the growth of the cowpeas is more strikingly shown in Plate 24. In figure A the pot on the right is the control, which received no barium compound. The pot in the middle received the same plant food as the control and 10 gm. of barium carbonate in addition. The pot on the left received 5 gm. of barium carbonate, but no calcium carbonate. It received the same amount of tricalcium phosphate as the other pots. One object in mind in this experiment was to ascertain whether there would be a tendency on the part of the plants in this pot to substitute barium for calcium in their growth. The peas germinated and came through the sand, made a stunted growth for a few weeks, and then died. The difference in the growth of the plants in the pot in the center and the one on the left shows very strikingly the toxic effect of barium carbonate in the absence of calcium carbonate. This experiment affords a very striking example in the plants in the center pot of the protective action of calcium carbonate on plants when grown in the presence of a toxic substance.

Figure B of Plate 24 shows the effect of barium carbonate on the growth of the roots of the cowpea plants grown in pots 1, 2, and 8; the plants on the right were the control and received no barium carbonate, the plants in the center received 0.5 gm. of barium carbonate, and plants on the left received 6 gm. of barium carbonate. It will be observed that the plants which grew in the presence of barium carbonate have made a markedly increased root growth over the control. It is also to be borne in mind that the plants in the center received only 0.5 gm. of the barium compound, whereas the ones on the left received 6 gm. or 12 times as much as the former, thus indicating that a very small amount of barium carbonate produces as great effect on the root growth as much larger amounts.

The compounds of strontium have many chemical and physical properties similar to those of barium and calcium. It was thought that a few comparative experiments showing what effect like compounds of barium and strontium might have upon the growth of plants would be of some interest in this connection. Therefore in the series of experiments that follow plants have been grown in the presence of both barium and strontium compounds and compared with similar plants grown in the presence of calcium compounds.

OATS

In a second series of experiments oats (*Avena sativa*) were grown in sand under conditions similar to those in which the cowpeas were grown in the previous experiment, with the same basal plant food ration as before.

After the young oat plants had reached a height of about 10 inches they were thinned to the same number of plants in each pot and as near equal in size as possible. The oats were brought to maturity and harvested and, after thoroughly air-drying, the grain was threshed and the weights of the air-dry grain and straw produced in each pot were determined. There were two control pots in this experiment, and the average weight of the grain and the straw from these two pots was taken as a check against other pots receiving compounds of barium or strontium in this series.

TABLE II.—*Effect of certain barium and strontium compounds upon the growth of oats—Second series*

Pot No. and treatment.	Weight of grain.	Gain or loss in weight of grain over control.	Weight of straw.	Gain or loss in weight of straw over control.
	Gm.	*Gm.*	*Gm.*	
Control pot 1	19.25	....	39.25	....
Control pot 2	17.40	....	34.50	....
Average	18.33	....	36.88	....
Pot 3+2 gm. of barium carbonate	18.50	+0.17	40.00	+ 3.12
Pot 4+5 gm. of barium carbonate	20.65	+2.32	44.75	+ 7.87
Pot 5+2 gm. of strontium carbonate	18.40	+ .07	37.15	+ .27
Pot 6+5 gm. of strontium carbonate	21.10	+2.77	46.25	+ 9.37
Pot 7+2 gm. of barium carbonate and 2 gm. of strontium carbonate	16.50	−1.83	37.25	+ .37
Pot 8+5 gm. of barium sulphate	11.00	−7.33	24.75	−12.13

TABLE III.—*Comparison of weight and percentage of nitrogen, phosphorus, and potassium per pot—Second series*

Pot No. and treatment.	Nitrogen.		Phosphorus.		Potassium.	
	Gm.	*Per cent.*	*Gm.*	*Per cent.*	*Gm.*	*Per cent.*
Control	0.3217	1.755	0.0752	0.41	0.0522	.285
Pot 3+2 gm. of barium carbonate	.3608	1.95	.0777	.42	.0518	.28
Pot 4+5 gm. of barium carbonate	.4120	2.00	.0847	.41	.0599	.29
Pot 5+2 gm. of strontium carbonate	.3367	1.83	.0773	.42	.0534	.29
Pot 6+5 gm. of strontium carbonate	.4579	2.17	.0886	.42	.0570	.27
Pot 7+2 gm. of barium carbonate+2 gm. of strontium carbonate	.2739	1.66	.0644	.39	.0429	.26
Pot 8+5 gm. of barium sulphate	.1727	1.57	.0418	.38	.0286	.26

In Table II is given the amount of barium or strontium compounds added to each pot, and the air-dry weights of the grain and the straw produced in each of the experiments. Table III gives a partial analysis of the grain showing the important constituents contained in the grain produced in each experiment.

Both barium carbonate and strontium carbonate have increased the percentage of nitrogen as well as the total weight of nitrogen when applied separately. Applied together, there is diminution. Barium sulphate has diminished both percentage and total weight of nitrogen.

The weights of grain and straw produced in this series of experiments show increased yields in all pots receiving either barium carbonate or strontium carbonate separately. The pot in which there was a mixture of the two carbonates shows a decrease in the yield of grain, while the yield of the straw is practically the same as that of the control. In the pot receiving barium sulphate there is a very marked decrease in both the grain and the straw, which shows the toxic effect of this compound when compared with the carbonate.

The analysis of the grain produced in each of the pots for nitrogen, phosphorus, and potassium shows a slightly greater content of each of these elements where there was an increase in the yields of the plants over that contained in the control. The last two pots in the series, No. 7 and 8, show a marked falling off in their nitrogen, phosphorus, and potassium content when compared with the controls and the other pots in this series. The maximum increase in protein—that is, $N \times 6.25$—amounts to 2.60 per cent over that of the control, and the grain containing it was grown in the presence of 5 gm. of strontium carbonate. The next highest result was obtained where 5 gm. of barium carbonate were present. The phosphorus and potassium content appears to be less affected by barium and strontium compounds than does nitrogen.

SPRING WHEAT

In the third set of experiments spring wheat (*Triticum aestivum*) was sown in pots containing sand to which was added the same basal plant-food ration as that added to the pots in the experiments with cowpeas and oats. The quantities of barium and strontium compounds added are given in Table IV. In addition to the barium and strontium carbonates certain pots received small amounts of what was claimed to be a very active commercial radio-active fertilizer. The amount of this material added to each pot is given in Table IV and is in accordance with the recommendations of the company marketing this material. After the young plants had reached a height of 6 or 8 inches, they were thinned to the same number of plants in each pot and were brought to a state approaching maturity. Unfortunately, when the wheat grains were in the dough stage, a careless attendant left the ventilators of the greenhouse open over Sunday and the sparrows came in and consumed a part of the grain growing in each pot; hence, the results for the grain in this series of experiments were discarded. The straw was allowed to ripen and was harvested. When thoroughly air-dried it was weighed. The results appear in Table IV.

TABLE IV.—*Effect of barium carbonate and strontium carbonate on the growth of wheat—Third series*

Pot No. and treatment.	Weight of dry straw. Observed.	Weight of dry straw. Average.	Gain or loss over control.
	Gm.	*Gm.*	*Gm.*
Pot 1 (control), no barium added	41.15	40.95	....
Pot 2 (control), no barium added	40.75		
Pot 3+2 gm. of barium carbonate	34.25	34.25	−6.70
Pot 4+2 gm. of barium carbonate	34.25		
Pot 5+2 gm. of strontium carbonate	38.50	38.12	−2.83
Pot 6+2 gm. of strontium carbonate	37.75		
Pot 7+2 gm. of barium carbonate+2 gm. of strontium carbonate	32.25	34.00	−6.95
Pot 8+2 gm. of barium carbonate+2 gm. of strontium carbonate	35.75		
Pot 9+2 gm. of barium carbonate+0.7 gm. of radio-active material	37.75	37.25	−3.70
Pot 10+2 gm. of barium carbonate+0.7 of gm. radio-active material	36.75		
Pot 11+0.7 gm. of radio-active material alone	37.35	36.67	−4.28
Pot 12+0.7 gm. of radio-active material alone	36.00		

The results in this series of experiments show a loss in the weight of the straw over the average weight of the straw in the control pots; however, the greater loss occurs in the barium pots. The strontium pots show a loss of one-half of that of the barium pots.

The radio-active fertilizer, when used alone or in combination with barium carbonate, did not affect the yield of the straw greatly, the yield in each case being less than that of the control.

WINTER WHEAT

In a fourth series of experiments winter wneat was sown in pots of sand containing the same basal plant-food ration as in previous experiments. Strontium nitrate was the compound subjected to experimentation in this series. The amounts added are given in Table V, which also gives the yields and average weight of the grains of wheat produced in in each experiment.

The results obtained in this series of experiments show abnormal yields in both grain and straw which probably are due to the large amounts of nitrate radical present rather than to the strontium ion, since strontium carbonate has in no instance given such marked increase in yields.

TABLE V.—*Effect of strontium nitrate on the growth of winter wheat—Fourth series*

Pot No. and treatment.	Number of grains per pot.	Weight of grain per pot.	Average weight per grain.	Weight of straw.
		Gm.	*Gm.*	*Gm.*
Pot 1 (control), no strontium nitrate	372	8.8872	0.0239	34.50
Pot 2 (control), no strontium nitrate	292	7.7650	.0266	27.50
Average	332	8.3261	.0252	31.00
Pot 3+5 gm. of strontium nitrate	369	11.9065	.0323	44.50
Pot 4+5 gm. of strontium nitrate	555	19.6108	.0353	52.00
Average	462	15.7586	.0338	48.25
Pot 5+10 gm. of strontium nitrate	561	17.6505	.03146	62.00

The results obtained in the analysis of the grain for nitrogen, protein, phosphorus, and potassium are interesting (Table VI). It will be seen that with the addition of strontium nitrate there is a decided increase in the nitrogen content of the grain and a decrease in the phosphorus, while the potassium content remains practically constant.

TABLE VI.—*Percentage of nitrogen, protein, phosphorus, and potassium contained in the grain produced in each of the foregoing experiments*

Pot No.	Nitrogen.	Protein (N×6.25).	Phosphorus.	Potassium.
Pot 1 (control)	1.68	10.50	0.36	0.18
Pot 2 (control)	1.71	10.68	.35	.24
Average	1.695	10.59	.355	.21
Pot 3	2.77	17.31	.22	.22
Pot 4	2.73	17.06	.23	.18
Pot 5	3.00	18.75	.23	.21

Having obtained unusual results in the yields and in the nitrogen content of the grain in the previous series of experiments, another, the fifth, series of pot experiments, similar to the ones that have been described, was carried out. This series was planned as a further check on the effect of strontium carbonate on the growth and the nitrogen content of wheat. The amount of strontium carbonate added to each pot and the yields of grain and straw produced are given in Table VII.

The seeds in pots 9 and 10 came up, and the stunted plants struggled for existence for the greater part of the time the other plants in this series were making a complete growth. The plants never reached a height of more than 10 inches, thus showing that strontium can not replace calcium in the growth of plants.

TABLE VII.—*Effect of strontium carbonate on the growth of wheat—Fifth series*

Pot No. and treatment.	Weight of grain.	Weight of straw.	Gain or loss in—	
			Grain.	Straw.
	Gm.	*Gm.*	*Gm.*	*Gm.*
Pot 1 (control)	10.00	36.50	....	....
Pot 2 (control)	9.00	34.50	....	....
Average	9.50	35.50	....	....
Pot 3+5 gm. of strontium carbonate	9.00	42.00	....	....
Pot 4+5 gm. of strontium carbonate	10.50	40.00	....	....
Average	9.75	41.00	+0.25	+5.50
Pot 5+10 gm. of strontium carbonate	11.50	39.50	....	....
Pot 6+10 gm. of strontium carbonate	13.00	40.00	....	....
Average	12.25	39.75	+2.75	+4.25
Pot 7+20 gm. of strontium carbonate	9.50	36.00	....	....
Pot 8+20 gm. of strontium carbonate	10.00	35.50	....	....
Average	9.75	35.75	+ .25	+ .25
Pot 9+10 gm. of strontium carbonate, no calcium carbonate	None.	(a)		
Pot 10+10 gm. of strontium carbonate, no calcium carbonate				

[a] Not weighed.

The results in the fifth series of experiments agree very closely with those of the other experiments in which strontium carbonate was used, both with respect to yields and the results obtained in the analyses of the grain (Table VIII). They also show conclusively that the increased yields obtained in the fourth series of experiments in which strontium nitrate was used were due to the greater amounts of nitrate being present which was assimilated and thus produced grains of wheat that contained 8 per cent more protein than was found in the control experiments, which showed a protein content equivalent to that of wheat grown under normal conditions.

The last two experiments in the fifth series show conclusively that strontium will not replace calcium in the growth of plants. They also show, however, that strontium carbonate in the absence of calcium carbonate is apparently less toxic towards plants than barium carbonate in the absence of calcium carbonate. It will be recalled that in the first series of experiments, in which an attempt was made to grow cowpeas in the presence of barium carbonate without calcium carbonate, all the plants died soon after coming through the sand, whereas in the case of the wheat plants in the presence of strontium carbonate and the absence of calcium carbonate the plants did not die soon after they were up, but maintained a struggling existence during the greater part of the time other plants in the series were making a normal growth, thus indicating that strontium carbonate is less toxic in the absence of calcium carbonate than barium carbonate.

TABLE VIII.—*Percentage of nitrogen, protein, phosphorus, and potassium in the grain grown in the pots in the fifth series of experiments*

Pot No. and treatment.	Nitrogen.	Protein (N×6.25).	Phosphorus.	Potassium.
Pot 1 (control)	1.69	10.56	0.31	0.20
Pot 2 (control)	1.66	10.38	.27	.18
Average	1.68	10.47	.29	.19
Pot 3	1.68	10.50	.33	.19
Pot 4	1.79	11.10	.35	.19
Average	1.74	10.80	.34	.19
Pot 5	1.61	10.06	.27	.19
Pot 6	1.69	10.56	.31	.17
Average	1.65	10.31	.29	.18
Pot 7	1.64	10.25	.27	.19
Pot 8	1.68	10.50	.31	.20
Average	1.66	10.38	.29	.19

CORN

In a sixth series of experiments corn plants (*Zea mays*) were grown in pots of sand containing the usual basal plant-food ration. To these pots were added varying amounts of barium and strontium compounds as shown in Table IX. Three corn plants were allowed to grow in each pot until the plants had tasseled and bloomed. As was to be expected, the corn plants were dwarfed on account of greenhouse conditions, the plants reaching a height of about 3 feet. After making their maximum growth the stalks were cut from the roots at the top of the sand. The fodder was stripped from the stalks. The roots were taken up and washed as free from adhering sand as possible. The different parts into which the plants were divided were kept separate, and after thoroughly air-drying, the weight of each of the parts determined and from thence the air-dry weights of the entire plants were computed. These results are given in Table IX.

The results in this series of experiments agree in a general way with those obtained in previous experiments with wheat and oats, where the same compounds of barium and strontium have been applied in equal quantities and under similar conditions.

TABLE IX.—*Air-dry weights of the corn plants in each of the experiments*

Pot No. and treatment.	Air-dry weights.				Gain or loss in weight when compared with the controls.			
	Roots.	Stalks.	Fodder.	Entire plants.	Roots.	Stalks.	Fodder.	Entire plant.
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
Pot 1 (control)	11.50	13.25	17.60	42.35	....	....	....	....
Pot 2 (control)	8.00	10.30	15.35	33.65	....	....	....	....
Average	9.75	11.77	16.47	38.00	....	....	....	....
Pot 3+2 gm. of barium carbonate	10.65	14.25	18.75	43.65	....	....	....	....
Pot 4+2 gm. of barium carbonate	12.10	8.25	19.30	39.65	....	....	....	....
Average	11.38	11.25	19.02	41.65	+1.63	−0.52	+2.55	+3.65
Pot 5+2 gm. of strontium carbonate	13.00	15.80	23.50	52.30	....	....	....	....
Pot 6+2 gm. of strontium carbonate	11.75	14.50	20.80	47.05	....	....	....	....
Average	12.38	15.15	22.15	49.68	+2.63	+3.38	+5.68	+11.68
Pot 7+2 gm. of barium carbonate and 2 gm. of strontium carbonate	14.75	13.00	20.25	48.00	+5.00	+1.23	+3.78	+10.00
Pot 8+2 gm. of barium nitrate	11.50	13.25	18.75	43.50	+1.75	+1.48	+2.28	+ 5.50
Pot 9+5 gm. of barium sulphate	10.75	8.00	14.25	33.00	+1.00	−3.77	−2.22	− 5.00
Pot 10+2 gm. of barium chlorid	11.50	7.50	19.25	38.25	+1.75	−4.27	+2.78	+ 0.25
Pot 11+5 gm. of barium carbonate	13.5	12.00	20.00	45.50	+3.75	+ .23	+3.53	+ 7.50
Pot 12+5 gm. of strontium carbonate	13.2	14.5	20.7	48.40	+3.45	+2.73	+4.23	+10.40

It will be noted again that the maximum increase in yield occurred in the presence of strontium carbonate, while equal amounts of barium carbonate produced only a very slight increase in the yield of the entire plants.

It is interesting to note that all of the roots in the corn experiment show some increase in yield over that of the controls, while in the weight for the stalks there are an equal number of minus and plus differences. In the weights of the fodders there is only one experiment in which the fodder produced is less than the control. In the weights for the entire plants barium sulphate gave a very decided negative difference. Both the sulphate and the chlorid reduced the yields in the stalks very decidedly.

TABLE X.—*Analyses of the corn fodder from the preceding experiments*

[The results are expressed as percentage of the moisture-free substance]

Pot No. and treatment.	Crude ash.	Insoluble residue (silica, etc.).	Ferric oxid (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).
Composite sample from pots 1 and 2 (control)	9.71	1.15	[a]0.44	1.03	0.92	3.22
Pots 3 and 4+2 gm. of barium carbonate	9.66	.84	.39	.89	.49	3.88
Pots 5 and 6+2 gm. of strontium carbonate	9.15	.91	.60	.92	.56	3.50
Pot 7+2 gm. of barium carbonate and 2 gm. of strontium carbonate	10.20	1.01	.44	1.00	.67	3.92
Pot 8+2 gm. of barium nitrate	9.15	1.14	.26	1.14	.67	3.61
Pot 9+5 gm. of barium sulphate	10.54	1.38	.58	1.34	.82	3.96
Pot 10+2 gm. of barium chlorid	11.07	1.21	.73	1.30	.58	3.91
Pot 11+5 gm. of barium carbonate	12.10	1.23	.83	.90	.60	4.34
Pot 12+5 gm. of strontium carbonate	9.53	.78	.14	.90	.50	3.86

[a] The irregularities occuring in the iron determinations are probably due to iron-oxid scales which may have come from the paint on the mill hopper, as some such scales were observed in some of the samples.

TABLE X.—*Analyses of the corn fodder from the preceding experiments*—Continued.

Pot No. and treatment.	Soda (Na_2O).	Barium sulphate ($BaSO_4$).	Strontium sulphate ($SrSO_4$).	Phosphorus pentoxid (P_2O_5).	Nitrogen (N).	Protein (N×6.25).
Composite sample from pots 1 and 2 (control)	0.86	....	....	0.22	1.16	7.22
Pots 3 and 4+2 gm. of barium carbonate.	.72	.059	....	.225	.96	6.01
Pots 5 and 6+2 gm. of strontium carbonate	.43	....	.15	.24	.81	5.115
Pot 7+2 gm. of barium carbonate and 2 gm. of strontium carbonate	.18	.035	.16	.27	.93	5.85
Pot 8+2 gm. of barium nitrate	.29	.044	....	.27	1.47	9.17
Pot 9+5 gm. of barium sulphate	.24	....	....	.32	1.44	9.00
Pot 10+2 gm. of barium chlorid	.24	Tr.	....	.28	.98	6.06
Pot 11+5 gm. of barium carbonate	.23	.02	....	.28	1.63	10.02
Pot 12+5 gm. of strontium carbonate	.37	....	.20	.27	.93	5.84

The results of the analyses of the fodders that were produced in each of the experiments show no very striking differences in the mineral composition of the fodders in any of the experiments (Table X).

It will be observed that only very small amounts of barium and strontium have been taken up by the plants growing in the presence of compounds of each of these elements.

SOYBEAN

In Plate 24, C, are shown four jars of soybean (*Soja max*) plants that were grown in cultural solutions. The plants in the jars on each end have been grown in a cultural solution containing no barium compound, whereas the two pots in the center have been grown in a similar solution containing barium nitrate. The plants in the two jars in the center received their sulphur from a solution containing taurin, while the plants in the end jars received their sulphur from a solution of magnesium and potassium sulphates. The differences to be observed in the growth of the two sets of plants is attributed to the presence of the barium nitrate which appears to have retarded the growth of the roots, stems, and foliage of the two sets of plants in the center.

When the very small amounts of the barium compounds that occur in the soil and the relatively insoluble state in which they occur are taken into consideration, one is led to wonder how it is that plants are able to extract even as much barium as can be determined in the ash of normal plants. Since no barium was found by careful examination of the residue from the evaporation of 25 liters of water flowing from a tile drain on the Station farm, although the presence of barium in the soil of the area drained had been proved by extracting 0.0508 gm. of barium sulphate from the hydrochloric-acid solution from 500 gm. of an average sample representing the first foot of soil from this field, it would appear that the roots of plants do not obtain their barium from the percolating soil water, but rather by some kind of selective action upon the soil particles. A determination of total barium in the soil of another field near by gave 0.08 per cent of barium sulphate, obtained by decomposing the soil with hydrofluoric and sulphuric acids.

CONCLUSIONS

From the results obtained in the different series of experiments in this investigation the following conclusions are drawn.

(1) Barium compounds in the absence of calcium carbonate are poisonous to plants; but barium carbonate in the presence of an excess of calcium carbonate apparently exerts a distinct stimulating influence on the growth of the plants studied.

(2) There is no tendency for barium to replace calcium in the growth of plants when calcium carbonate is omitted from a plant-food ration under the conditions of these experiments.

(3) Strontium compounds have in most instances given larger increased yields than barium compounds.

(4) Strontium carbonate can not be substituted for calcium carbonate in the growth of plants under the conditions studied, though strontium carbonate is less toxic to plants in the absence of calcium carbonate than barium carbonate.

(5) Neither barium nor strontium compounds can be looked upon as important plant foods, although the presence of small amounts of the carbonate of each of these elements has given increased yields that are noteworthy in most instances.

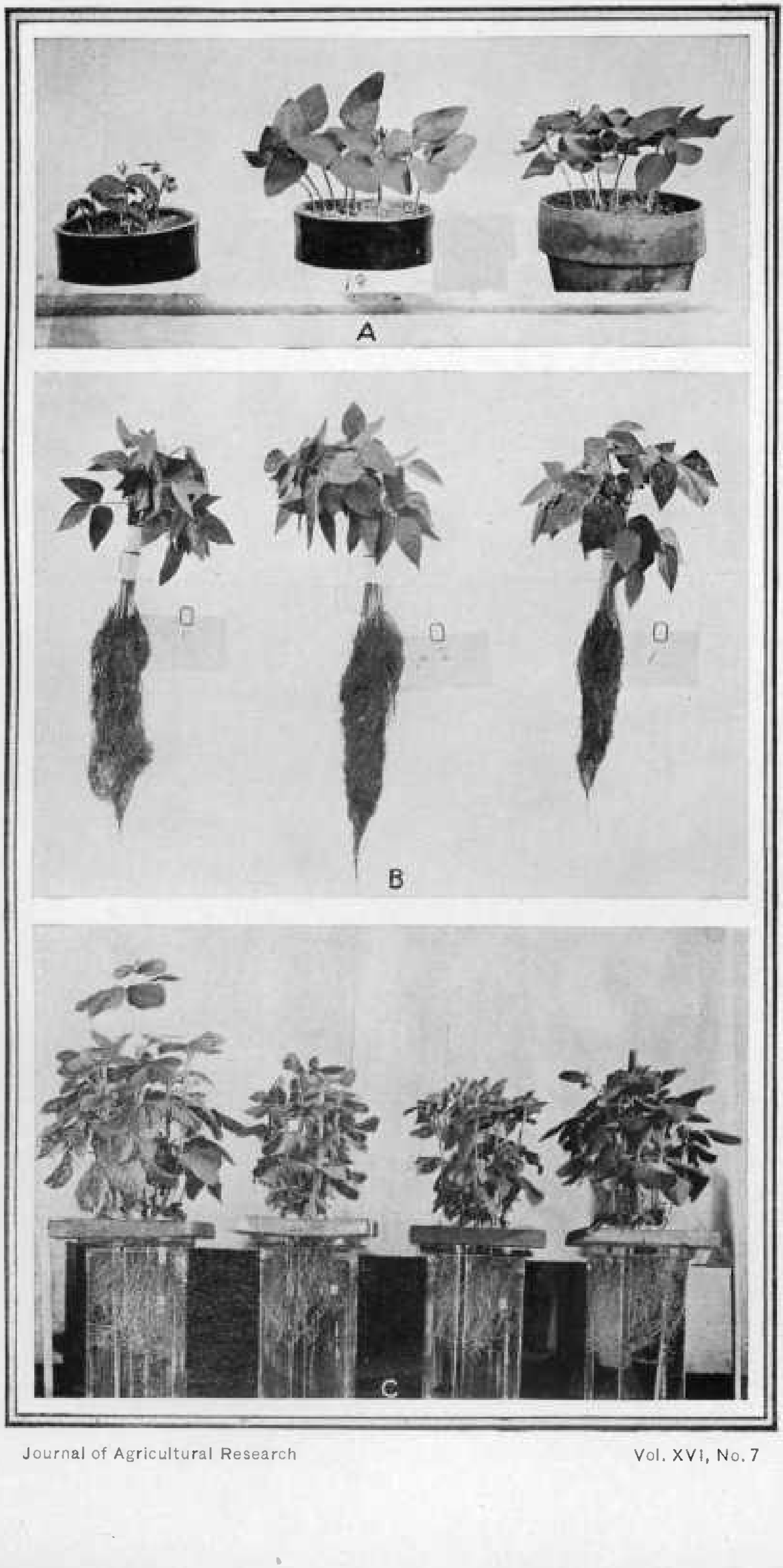
(6) Barium and strontium carbonates accelerated the growth of the roots of such plants as were examined.

(7) Increasing the amount of strontium nitrate gave a corresponding increase in the nitrogen content of wheat.

(8) No barium compounds were found in the residue obtained upon evaporating 25 liters of drainage water collected from the drain tiles on the Station farm, which would indicate that the barium found in plants is taken up in place by the plant roots.

PLATE 24

A.—Effect of barium on the growth of cowpeas with and without calcium carbonate.
B.—Stimulating effect of barium on root growth of cowpeas.
C.—Effect of barium on the growth of soybeans.


A
B
C